A Unique System Approach to Deliver Best FPGA/SoC Paired With Validated and Optimized Power Solutions

Arrow Vision Presentation

Jul 18th, 2013 rev 1.6

Agenda

- Introduction – Altera acquisition
- Enpirion power products and technology
- FPGA power challenges
- PowerSoC benefits
- Reference design: 4 validated solutions

FPGA + Power : One Company, One Solution

Altera to Deliver Breakthrough Power Solutions for FPGAs with Acquisition of Power Technology Innovator Enpirion

Industry's Most Integrated Power Solutions Reduce Power, Provide Smallest Form Factor and Simplify System Design

San Jose, Calif., May 14, 2013—Altera Corporation (NASDAQ: ALTR) today announced it has signed a definitive merger agreement to acquire Enpirion, Inc., the industry's leading provider of high-efficiency, integrated power conversion products known as PowerSoCs (power system-on-chip). The combination of Altera's FPGAs with Enpirion's PowerSoCs will offer customers higher performance, lower system power, higher reliability, smaller footprint and faster time-to-market.

"Power is increasingly a strategic choice for product differentiation in communications, computing and enterprise, and industrial applications," said John Daane, president, CEO and chairman of Altera. "By adding a power group to Altera, we will bring even more value to system-level designs. Altera's FPGA roadmap will be enhanced significantly with the addition of Enpirion's power technologies."

Ashra[illegible] founder an[illegible] CEO of Enpirion[illegible] will se[illegible] a Fellow[illegible]

Acquisition completed May 21st 2013

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Why Acquire a Power Company?

- FPGA power requirements are getting more complex
  - Number of rails, tolerances, load requirements, power up sequencing and layout
- Power is becoming a strategic differentiator for FPGA customers
- Adding power allows Altera to optimize system-level FPGA solutions

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Who Is Enpirion?

- Founded in 2001 by Bell Labs experts
- Industry's most advanced PowerSoCs
- More than 60 released products
- 100 million units shipped
- Key Enpirion markets
  - Enterprise
  - Communications
  - Industrial
  - Test & Measurement

POWER ELECTRONICS TECHNOLOGY

EDN INNOVATION

EDN HOT 100

analogZONE Product of the Year

EDN HOT 100 products WINNER

embedded AWARD 2013

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Enpirion PowerSoC Leadership in Integrated Power Conversion

High Efficiency + Low Noise

- Up to 96% efficiency with low ripple
- Lower system power

Increased System Reliability

- Fully simulated, characterized, and validated power system
- Fewer components

Ease-of-Use; Faster Time-to-Market

- Simple design flow with fewer iterations
- Lower development costs

Smallest Footprint

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Enpirion PowerSoC, a Key Brand within Altera

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POWERING YOUR INNOVATION

MAX Series	Cyclone Series	Arria Series	Stratix Series	ENPIRION
CPLDs	***FPGAs***	***FPGAs***	***FPGAs***	***PowerSoCs***
Lowest Cost, Lowest Power	*Cost/Power Balance SoC & Transceivers*	*Mid-range FPGAs SoC & Transceivers*	*Optimized for High Bandwidth*	*High-efficiency Power Management*

RESOURCES

Embedded Soft and Hard Processors

Nios® II

ARM

Design Software

QUARTUS® II

DSP Builder

Development Kits

Intellectual Property (IP)

- Industrial
- Computing
- Enterprise

Enpirion PowerSoC: Target Customers / Applications

Customer challenges to solve

- Minimizing power loss
- Board space constraint
- Noise sensitivity
- Time-to-market pressures; fewer resources
- While improving Cost & Reliability!

PowerSoC Benefits

- High efficiency, smallest size
- Excellent noise/transient performance
- Simple, low risk power design
- Highest reliability, fewest components

Power FETs
PWM Controller
Inductor
Compensation Circuit

Target Markets

Enterprise userver

Telecom

Embedded/ Industrial

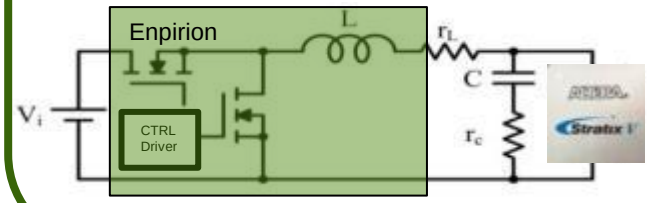
Storage

Test & Measurement

Optical Networking

Target Specifications

- Step down conversion $V_{IN} < V_{OUT}$
- Input voltages: 3.3 V, 5 V, 12 V (V_{IN} <15 V)
- Output voltage: 0.6 V to 6 V
- Output current: 300 mA to 15 A (60A in //)



Loads
- FPGA
- Digital Semi
- Memory
- I/O

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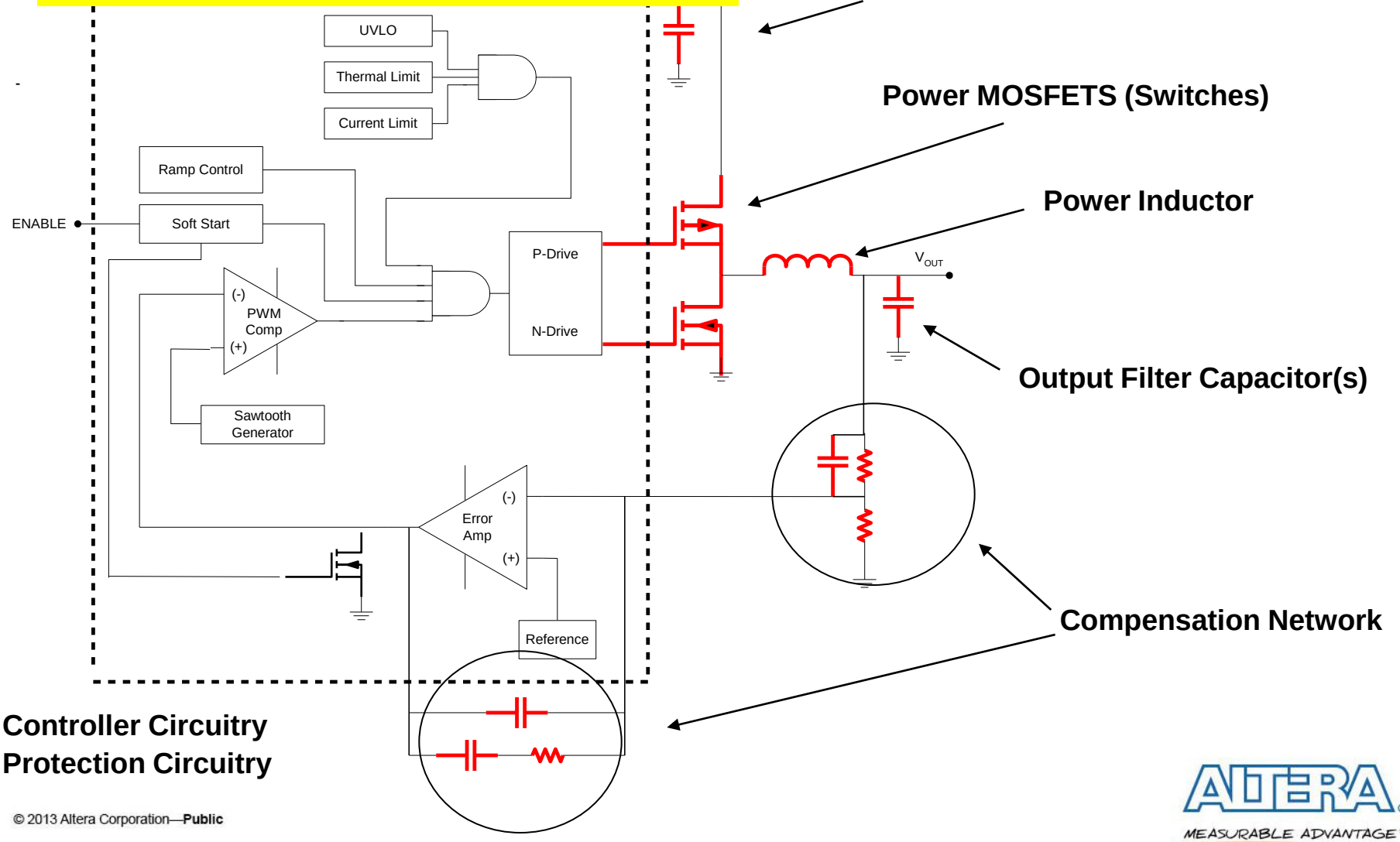
Challenges For FPGA or Digital Semiconductor Power

Problem Statement

1. **Limited space available on PCB**
   - PCB size is constrained due to industry standard form-factors while functionality increases (more ports, more memory, more functions on-board)
   - Market forces require ever smaller product form-factor (Ex: cabinet→rack→card)
2. **Enterprise, Industrial, Telco, Netcom markets demand higher reliability**
   - Solution assembled from multiple vendors and components not designed, qualified, tested as system
   - High part counts drive lower reliability and lower assembly yields
   - Many power passives are high reliability risk such as electrolytic bulk capacitors
3. **Customers need greater conversion efficiency**
   - Thermal limitations require less heat generation (conversion loss = heat);
   - OPEX considerations drive lower cooling costs; poor efficiency = higher cooling costs
4. **High-speed SERDES, RF circuits, PLLs, sensitive to noise**
   - DC-DC converter noise can affect IO signal integrity, SERDES jitter, RF contamination
5. **Limited design resource and fast time to market requirements**
   - Traditional power implementations require multiple design cycle iterations, multiple re-spins
   - Power design is a highly specialized discipline; many customers have limited analog resources

Key Components of a Switch-Mode DC-DC Converter

How do you Make it Smaller?



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Relationship Between Switch Frequency and Size

- **Inductor:**

$$L = \frac{V_{OUT}\left(1 - \frac{V_{OUT}}{V_{IN}}\right)}{\Delta I_{OUT} F_{SWITCH}}$$

  - Inversely proportional: higher the frequency, the smaller the inductor value
- **Input Filter Capacitors**

$$C_{IN} = \frac{D(1-D)}{\Delta V_{IN} F_{SWITCH}} \qquad \text{where} \left[D = \frac{V_{OUT}}{V_{IN}}\right]$$

  - Inversely proportional: higher the frequency, the smaller the capacitor value
- **Output Filter Capacitors**

$$C_{OUT\_min} = \frac{\Delta I_{OUT}}{\Delta V_{OUT} F_{SWITCH}}$$

  - Inversely proportional: higher the frequency, the smaller the capacitor value
- **High Switch Frequency Allows Smaller Component Values Thereby Enabling PowerSoC Integration**

However, Nothing Comes for Free!

- **While Higher Switching Frequency Enables Smaller Filter Component Values, It Increases Switch Losses:**

$$P_{LOSS\_MOSFET} = \underbrace{I^2R_{on}}_{\text{Conduction Losses}} + \underbrace{C_{iss}V^2_{GS}F_{SW} + C_{oss}V^2_{DS}F_{SW}}_{\text{Switching Losses}}$$

R_{on} ---- On-Resistance

C_{iss} ---- FET Equivalent Input Capacitance

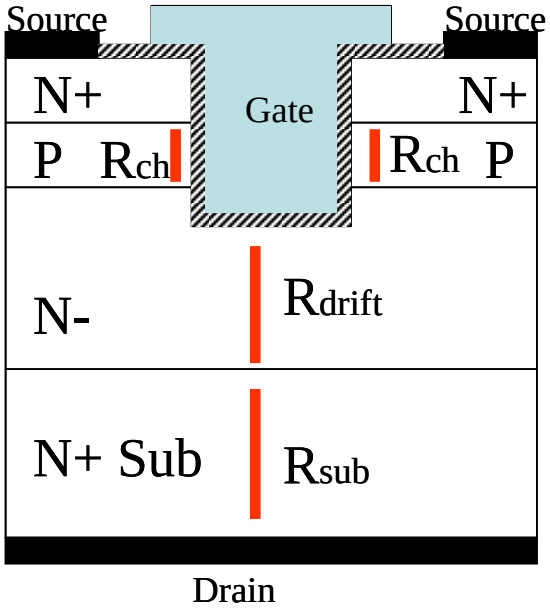
C_{oss} ---- FET Equivalent Output Capacitance

Enpirion Power MOSFET Design Reduces Switch Loss

- **Enpirion power MOSFET design reduces equivalent Input and Output capacitances by 10x so F_{SWITCH} can be 10x higher than competitors for similar switch loss**

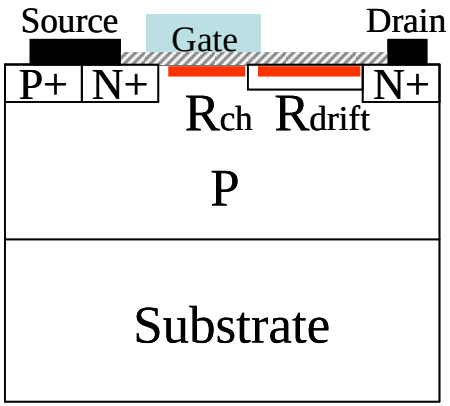
Industry:

UMOSFET



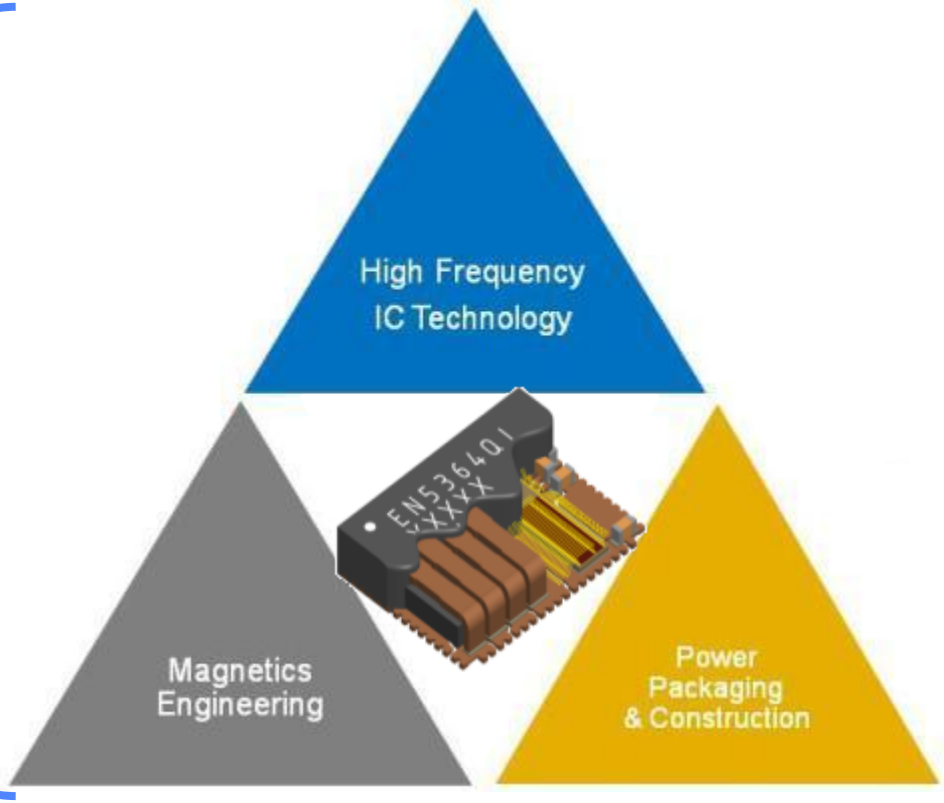
Enpirion: Small & High Performance

EDMOS



Key Enablers of High Density PowerSoC

3 Focused Technology Development



DC-DC System Engineering

Inductor Selection
Capacitor Selection
Power Stage Analysis
Controller & Compensation Design
Stability
Time Domain Simulation
Validation
Production Testing

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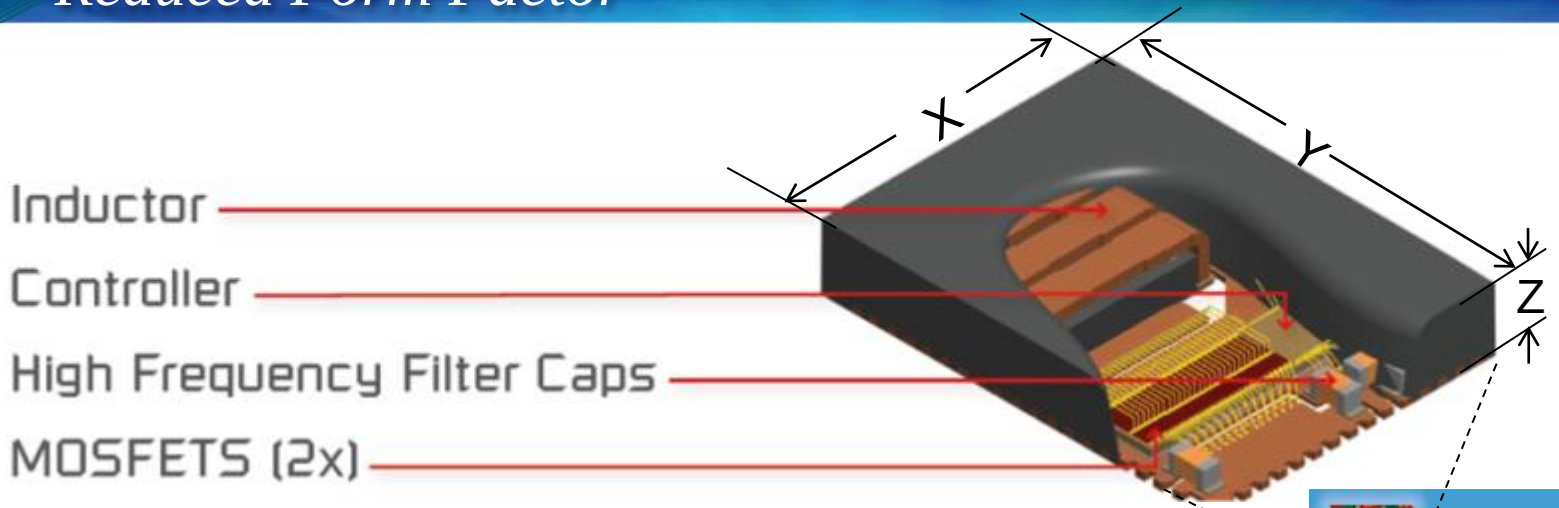
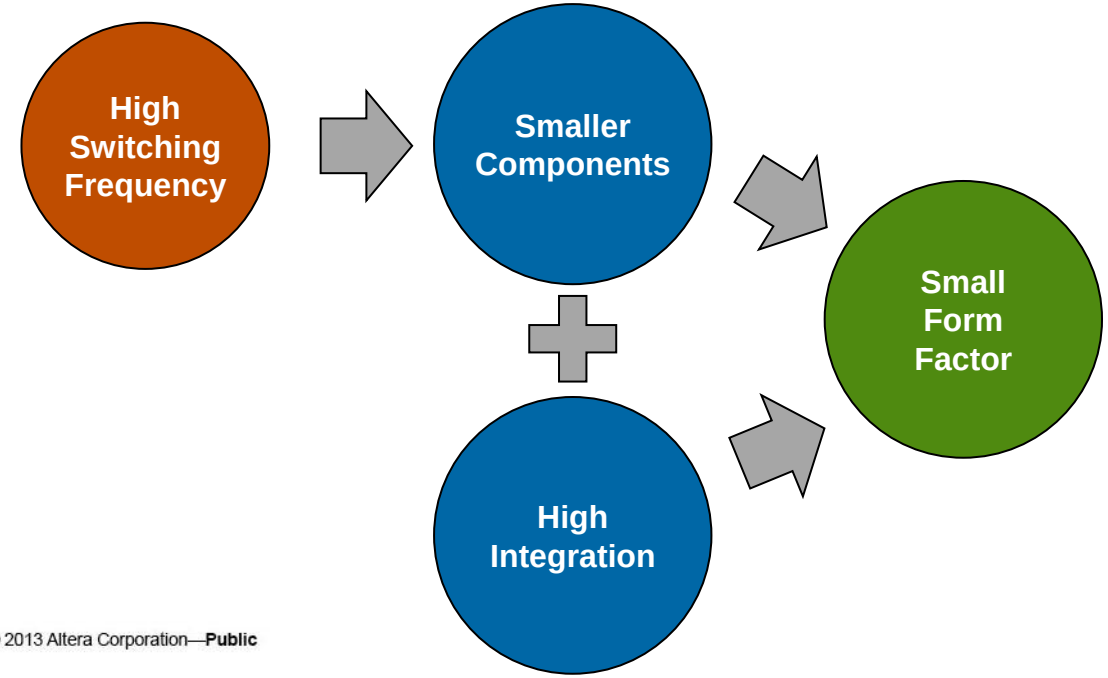
Powering Your Innovation

Reduced Form Factor





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Enpirion PowerSoC Product Benefits

Enpirion PowerSoCs Offer a Clear and Tangible Value Proposition

- **Smallest Solution Size, Low Part Count**
- **High Efficiency, High Performance**
- **High Reliability; Typically 280,000 Years MTBF**
- **Low Noise Design; Low Ripple, Low EMI**
- **Ease of Design; Fast Design Cycle; First Pass Success**
- **Designed as a System, Qualified as a System, Tested as a System for Assured Reliability and Assured Performance**

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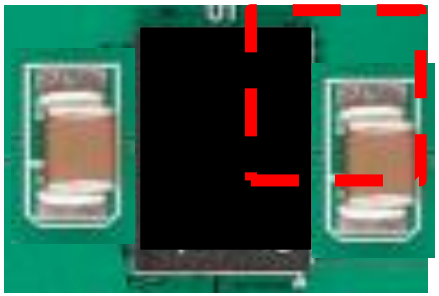
Enpirion PowerSoCs Deliver Highest Power Density

From 20% to 50%

power density reduction

Enpirion PowerSoC	***Competitor A*** *(Modules)*
1X	2X



20% lower height than the nearest module competitor

Comparison for 5V V_{IN}, 4A PowerSoC

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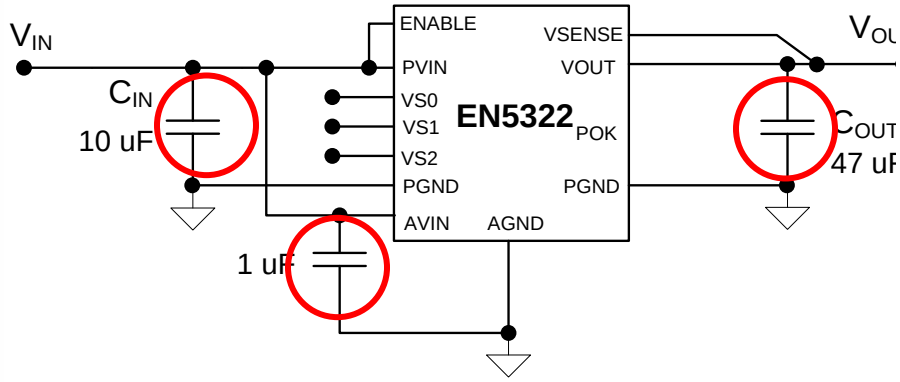
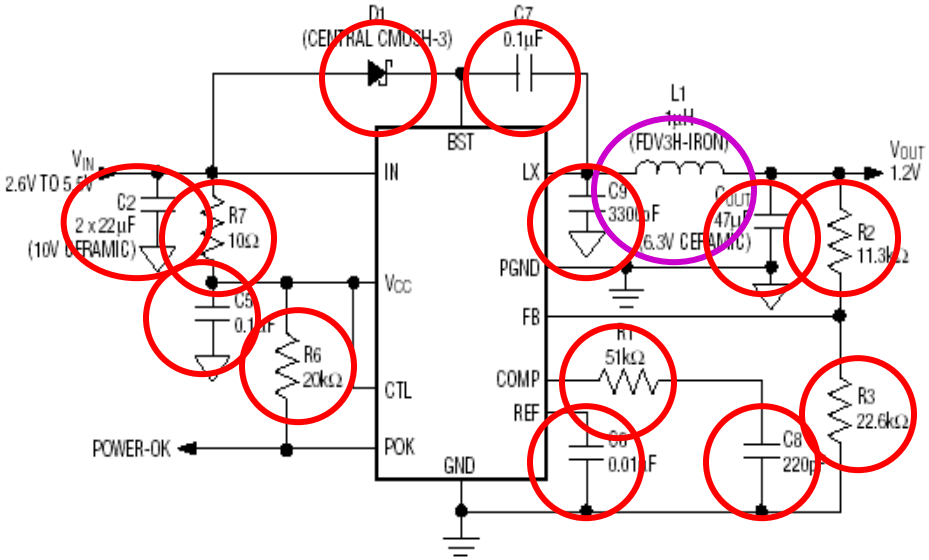
Value Proposition: Low Part Count

- **Fewer placements means higher assembly yield**
- **Fewer components means higher reliability**
- **Enpirion requires ceramic Caps only; no POSCAP, OSCON**
- **Fewer components means lower BOM cost**

Typical Part Count



Competitor Typical Part Count



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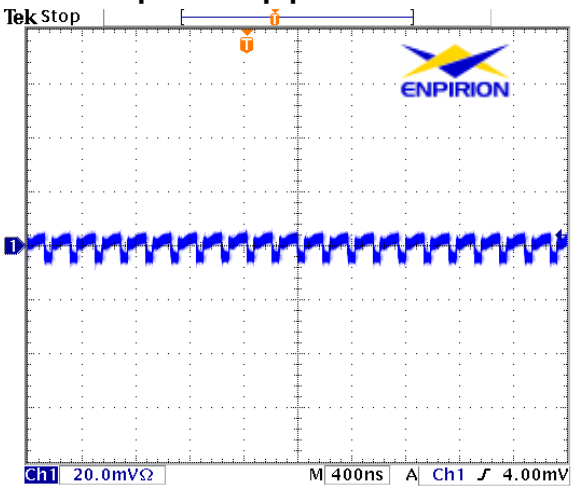
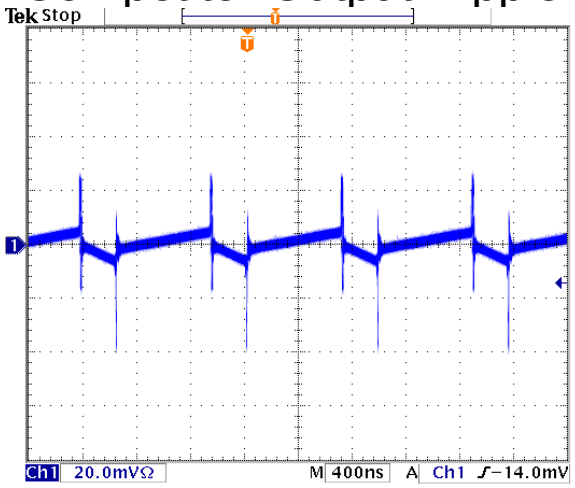
Value Proposition: Low Ripple, Low EMI

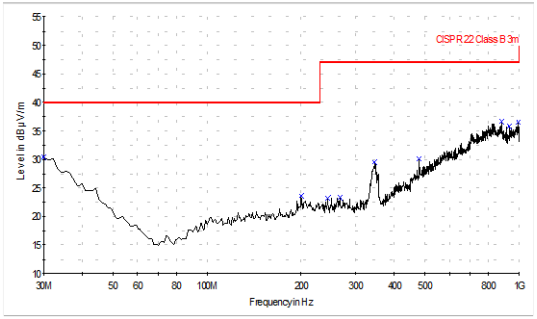
Output Ripple



Competitor Output Ripple

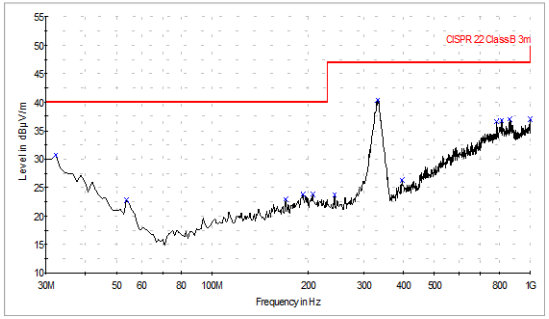


Radiated Emissions



4/27/10, MJO# 41632 - Enpirion Inc., EN6360QI, 5Vin, 1.5V out, 0.2 Ohm
30MHz - 1GHz Vertical Peak Scan (90 Degree Table Angles)

Competitor Radiated Emissions



4/27/10, MJO# 41632 - Enpirion Inc., ISL8201M 5Vin, 1.5V out., 0.14 Ohm
30MHz - 1GHz Vertical Peak Scan (90 Degree Table Angles)

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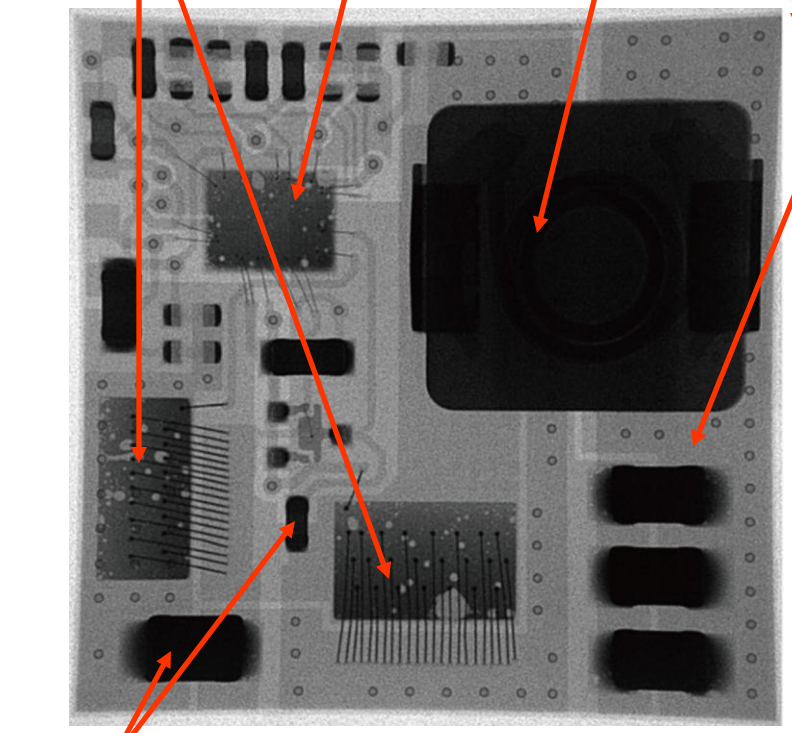
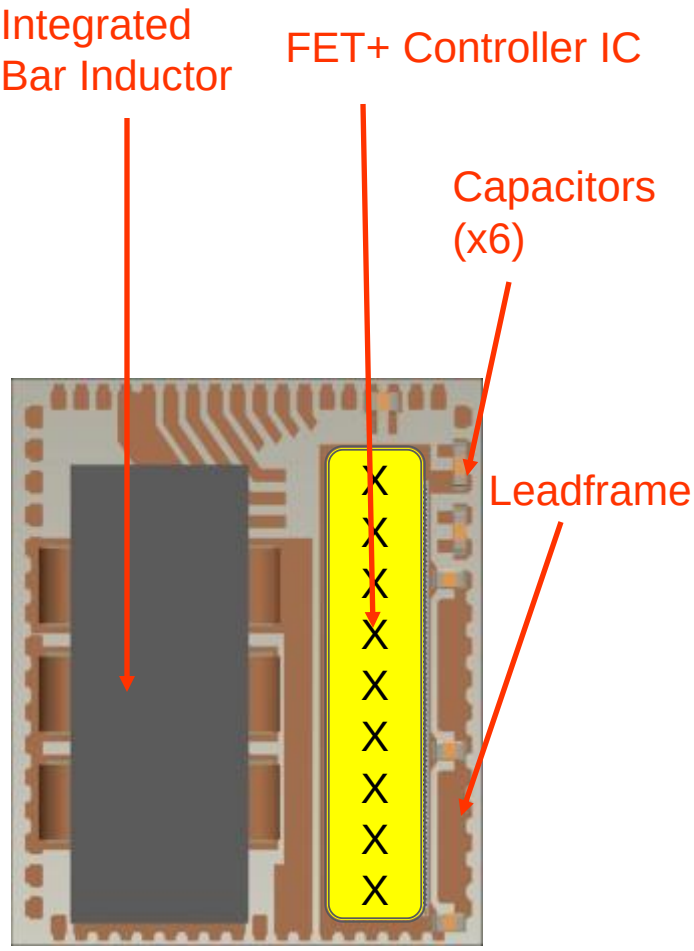
Superior Integration vs. uModules



15x15mm



10x11mm EN63A0

Superior Integration

Value Proposition: High Reliability

- **Designed as a System, Qualified as a System, and Tested as a System!**
- **Device FIT rate = 0.4 (MTBF = 280,000 yrs)**
  - **@ 55°C, 1.0eV activation energy, 60% confidence level**
- FIT Rate based on aggregate HTOL (High Temperature Operating Life) data

Item	Test	Standard	Test Condition
1	High Temperature Operating Life (HTOL)	JESD22-A108C	125°C, 5.5 to 15Vin, 1000 hours
2	Temperature Humidity Bias with Pre-Conditioning (Note 1)	JESD22-A101B	85°C, 85%RH, 5.5 to 15Vin, 1000 hours
3	Accelerated Moisture Resistance Unbiased HAST or Autoclave with Pre-conditioning (Note 1)	JESD22-A118B JESD22-A102C	85%RH, 130°C, 96 hours 100%RH, 121°C, 96 hours
4	Temperature Cycle with Pre-Conditioning (Note 1)	JESD22-A104C	–65°C to +150°C / 500 cycles Condition C, Soak Mode 4
5	High Temperature Storage (HTS)	JESD22-A103C	150°C, 1000 hours, Condition B
6	Electrostatic Discharge (ESD) – Human Body Model (HBM)	JESD22-A114E	2000V minimum Class 2
	Electrostatic Discharge (ESD) – Field Induced Charge Device Model (CDM)	JESD22-C101C	500V minimum
7	Latch Up	JESD78A	Class I & II
8	Solderability	JESD22-B102D	Method 1; Lead-Free

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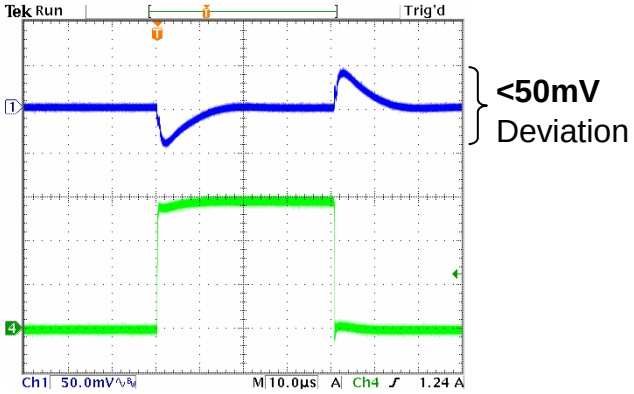
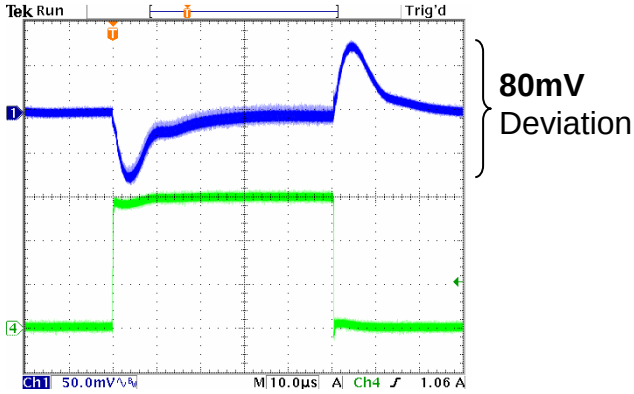
Value Proposition: Transient Performance

- **Enpirion PowerSoCs product have very high loop bandwidth**
  - Allow use of ceramic only capacitance (smaller size, cost and performance)
  - Smaller output deviation meeting stringent max voltage requirement
  - Voltage mode

Enpirion: EN5337QI
Solution Size: 75mm2

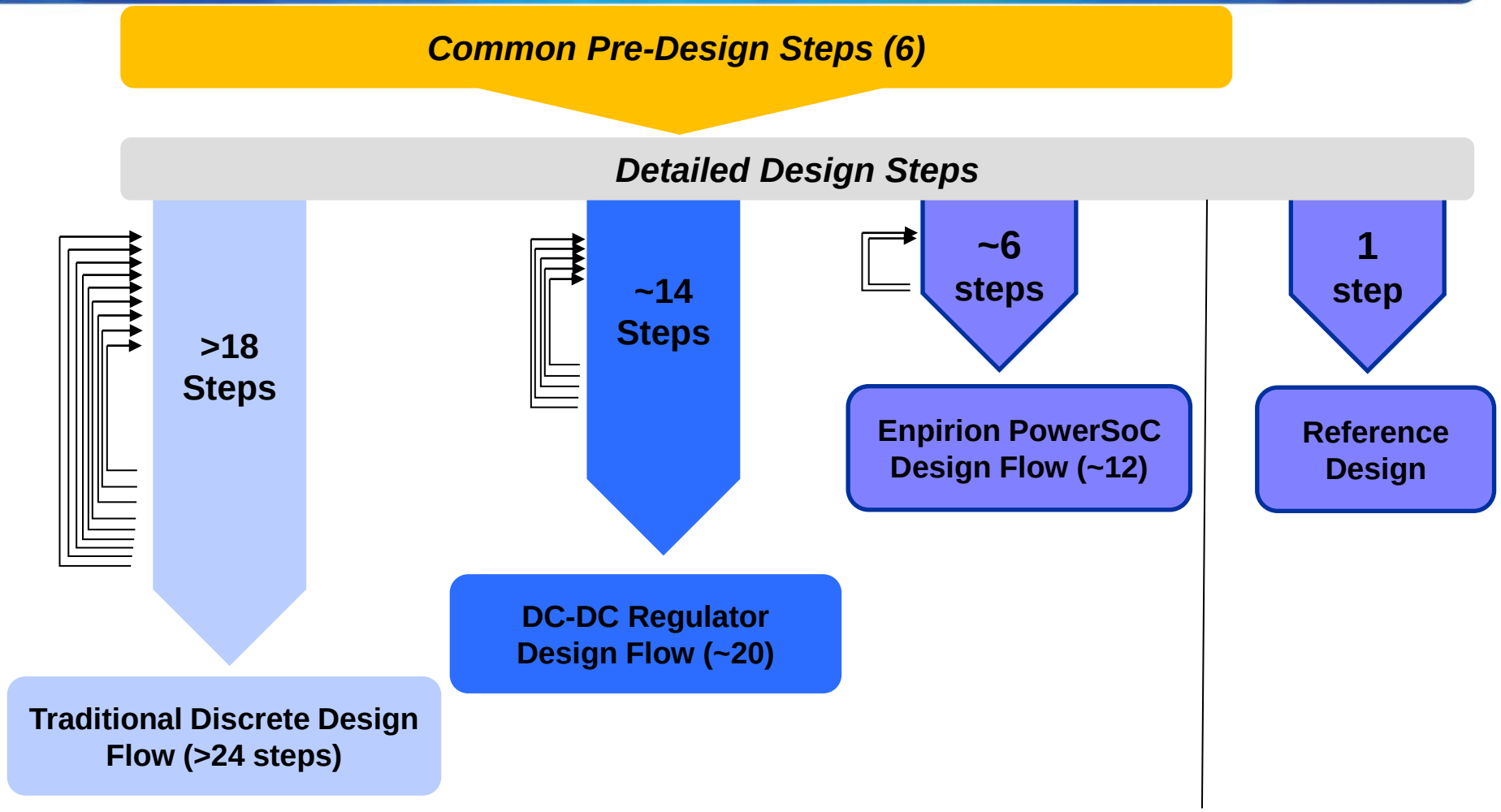


Competitor
Solution Size: 216mm2



0 - 3A Slammer Load Transient

Ease of Design – 1 Step with Reference Designs



***Enpirion PowerSoC ~ 2X Faster Design Time** & High Probability of 1st Pass Success*

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Altera Validated Solutions Simplify Design Process

Reduce Risk, Effort, Time, Costs

Step 1

- Run Altera Power Optimizer / Estimator

Step 2

- Select Altera Validated PowerSoC

Step 3

- Use Validated FPGA Power Schematics / Gerbers / etc.

Faster Time-to-Market

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Enpirion PowerSoC for LDO Replacement

- **Customers tend to use LDO's to power noise sensitive transceiver supply rails due to their low noise characteristic, but, at the cost of power loss and thermal dissipation.**

- **Altera's Enpirion PowerSoCs provide the low noise and simple design of an LDO, but provide the high conversion efficiency of a switch-mode DCDC converter.**

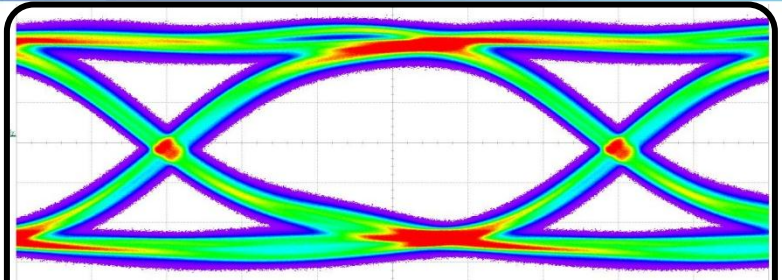
- **To demonstrate this thesis, a Stratix V GX FPGA board was used to compare jitter and efficiency for a bench supply, a LDO regulator, and Altera's Enpirion PowerSoC**
  - The jitter was essentially the same for all three supplies
  - The efficiency was 83% for the PowerSoC vs 30% for the LDO

- **PowerSoC CAN supply sensitive SERDES rails with no jitter degradation and with a dramatic improvement in power loss**

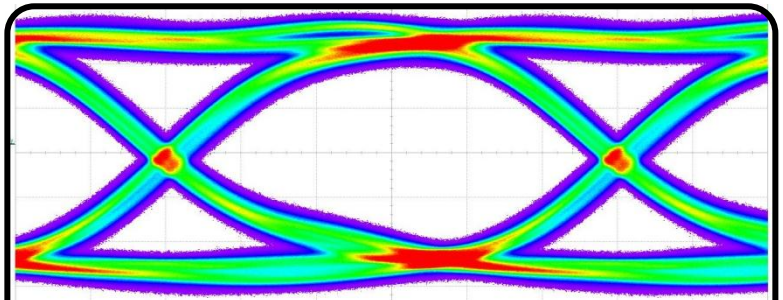
LDO Replacement for Transceiver Power

- **Brief Introduction to Power Conversion:**
  - Linear Regulator
    - Utilizes a resistive element and a feedback network to regulate voltage
    - Benefits: Small Solution, low part count, low noise, simple design
    - Drawbacks: low conversion efficiency, increased thermal dissipation
  - Switch-mode DCDC Converter
    - Utilizes magnetic storage and a feedback network to regulate voltage
    - Benefits: High conversion efficiency, lower thermal dissipation
    - Drawbacks: larger solution size, noise source, complex design, more parts
  - Altera's Enpirion PowerSoC
    - Benefits: High efficiency, low part count, low noise, low design complexity
- **What is a PowerSoC?**
  - A highly integrated switch-mode DCDC converter
    - Integrated controller, MOSFET switches, and Inductor in a single package
    - Integration reduces noise and simplifies design complexity.
    - Designed as a complete system, qualified as a complete system, and production time tested as a complete system, for high reliability and 95% first pass success

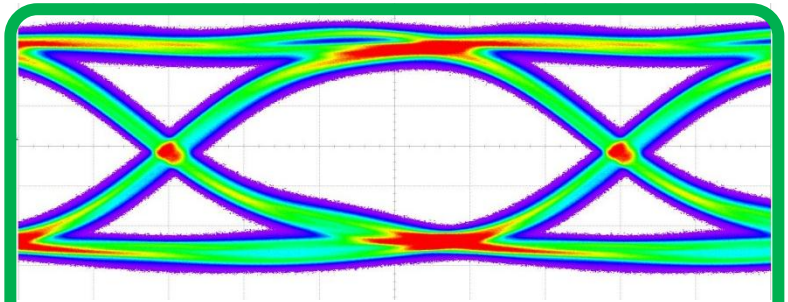
PowerSoC, Quiet and Efficient for SERDES



Stratix V GX FPGA Board – Bench Supply 11.3Gbps;



Stratix V GX FPGA Board – LDO Supply 11.3Gbps



Stratix V GX FPGA Board – PowerSoC Supply 11.3Gbps

Configuration	Tj (ps)	Rj (fs)	Efficiency*
Bench Supply	19.55	682	-
LDO	19.89	685	**30%**
PowerSoC	19.32	681	**83%**

* VIN=3.3V, VOUT=1.0V

EN6337QI on VCCRT_GXB, VCCA_GXB

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Reference Designs

Validated Solution Altera FPGA/SoC and Power

4 Reference Designs

- **Availability**
  - 4Q'13
- **Fully tested solutions**
- **Turn key design**
  - Characterization data
  - Schematic
  - Layout files
- **Benchmarking**
  - Proven performance advantage
  - Power, size, noise, cost

Broad support for 28 nm portfolio

Cyclone V SoC		Cost Efficiency Space
Cyclone V		Cost Efficiency Space
Arria V		Efficiency Cost
Stratix V		Efficiency XCVR noise

Reference Designs Collateral

- User guide and reference manual
- Schematics
- Board Layout
- Gerber files for Board
- Gerber files for individual power components
- Complete BOM list
- Validation data pack
- Full source for test environment

Alignment with FPGA Roadmap

Alignment with FPGA Roadmap

Existing power products

Cost
Efficiency
Space

Cost
Efficiency
Space

Efficiency
Cost

Efficiency
XCVR noise

Other key features
Ease of use, TTM, Reliability

Future products

Key power requirements Stratix 10

- Higher Power
- Tight VOUT voltage tolerance
- Intelligent voltage control
- Low noise Transceiver power
- Comms Bus for control/telemetry
- Higher current
- Low profile (<2.5mm for PCIe)
- Performance (efficiency, transient)

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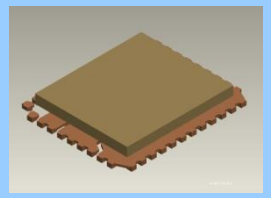
What's Next?

- **Sneak Peak at Power Train and High Current Digital Solution**

Monolithic Powertrain
ETxx family

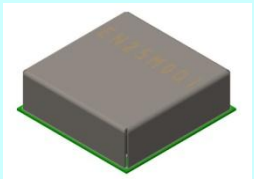
I_{OUT}:20-50 A
Smart supply
Telemetry



IOUT	Size (mm^2)
50A	5.5x7.5
40A	5.5x6.5
30A	30
20A	25
10A	22

Integrated Digital Module
25Mx Family

12V
I_{OUT} >10A
Bus: SVID/SMBus
Telemetry



IOUT	Size (mm^2)
30A	200
20A	170
15A	130
10A	120

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Summary

- **Altera now offers complete, validated, solutions to our customers; power for FPGA and for all other system blocks to support our customer's requirements.**
- **Altera's Enpirion Power Solutions provide:**
  - Smallest solution size and highest efficiency vs density
  - Low noise and ripple for efficiently powering SERDES and PLL
  - Excellent transient performance
  - Very high reliability
  - And, very easy design for fastest time to market (and revenue for our customers)
- **Fully validated reference designs are available in Q4'13 for:**
  - Stratix V GX, Arria V GX, Cyclone V GT, Cyclone V SoC
- **Altera is in the power business and we are ready now!**

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Thank You

Product Selector Guide

PN	Iout (A)	Vin (VDC)	Vo Range (VDC)	Pkg (pins)	Pkg Size (mm) L	W	H	Solution Size mm2	Resistor Divider VOUT Set	VID VOUT Set	POK Flag	Programmable Soft Start	Pecision Enable	Input Synchronization	Clock Output	Parallel Capability	Programmable Frequency	Light Load Mode (AB-LLM)	Pre-Bias Startup	Over Voltage Protection	Over Current Protection	Over Temp Protection	Approved for IBC usage	VDDQ Tracking	External Reference	Margining Pin
STANDARD 5V INPUT PRODUCTS																									
EP5348QI	0.4	2.4 - 5.5	0.6 - VIN	uQFN14	2	1.75	0.9	20													•	•				
EP5357xUI	0.6	2.4 - 5.5	0.6 - VIN	uQFN16	2.5	2.25	1.1	14	•	•								•			•	•				
EP5358xUI	0.6	2.4 - 5.5	0.6 - VIN	uQFN16	2.5	2.25	1.1	14	•	•											•	•				
EP5368QI	0.6	2.4 - 5.5	0.6 - VIN	QFN16	3	3	1.1	21	•	•											•	•				
EP5388QI	0.8	2.4 - 5.5	0.6 - VIN	QFN16	3	3	1.1	28	•	•											•	•				
EP53A7xQI	1	2.4 - 5.5	0.6 - VIN	QFN16	3	3	1.1	21	•	•								•			•	•				
EP53A8xQI	1	2.4 - 5.5	0.6 - VIN	QFN16	3	3	1.1	21	•	•											•	•				
EP53F8QI	1.5	2.4 - 5.5	0.6 - VIN	QFN16	3	3	1.1	40	•		•										•	•				
EN5319QI	1.5	2.4 - 5.5	0.6 - VIN	QFN24	4	6	1.1	55	•		•										•	•				
EN5322QI	2	2.4 - 5.5	0.6 - VIN	QFN24	4	6	1.1	58	•	•	•										•	•				
EN5329QI	2	2.4 - 5.5	0.6 - VIN	QFN24	4	6	1.1	55	•		•										•	•				
EN5337QI	3	2.4 - 5.5	0.75 - VIN	QFN38	4	7	1.85	75	•		•	•		•							•	•				
EN5339QI	3	2.4 - 5.5	0.6 - VIN	QFN24	4	6	1.1	55	•		•										•	•				
EN5365/6QI	6	2.4 - 5.5	0.75 - VIN	QFN58	10	12	1.85	229	•	•	•	•				•				•	•	•				
EN5367QI	6	2.5 - 5.5	0.75 - VIN	QFN54	5.5	10	3	210	•		•	•		•		•					•	•				
EN5395QI	9	2.4 - 5.5	0.75 - 3.3	QFN58	10	12	1.85	277		•	•					•					•	•				
EN5396QI	9	2.4 - 5.5	0.75 - VIN	QFN58	10	12	1.85	282	•		•					•					•	•				

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Product Selector Guide

PN	Iout (A)	Vin (VDC)	Vo Range (VDC)	Pkg (pins)	Pkg Size (mm) L	W	H	Solution Size mm²	Resistor Divider VOUT Set	VID VOUT Set	POK Flag	Programmable Soft Start	PecisionEnable	Input Synchronization	Clock Output	Parallel Capability	Programmable Frequency	Light Load Mode (AB-LLM)	Pre-Bias Startup	Over Voltage Protection	Over Current Protection	Over Temp Protection	Approved for IBC usage	VDDQ Tracking	External Reference	Margining Pin
6V INPUT PRODUCTS																										
EN5311QI	1	2.4 - 6.6	0.6 - VIN	QFN20	4	5	1.1	36		•											•	•	•			
EN5335/6QI	3	2.4 - 6.6	0.75 - VIN	QFN44	7.5	10	1.85	157	•	•	•	•								•	•	•	•			
EN6337QI	3	2.4 - 6.6	0.6 - VIN	QFN38	4	7	1.85	75			•	•		•				•			•	•	•			
EN6347QI	4	2.4 - 6.6	0.6 - VIN	QFN38	4	7	1.85	75			•	•		•				•			•	•	•			
EN5364QI	6	2.4 - 6.6	0.6 - VIN	QFN68	8	11	1.85	160			•		•	•	•	•			•	•	•	•	•			•
EN6360QI	8	2.4 - 6.6	0.6 - VIN	QFN68	8	11	3	195	•		•		•	•	•	•	•		•		•	•	•			
EN5394QI	9	2.4 - 6.6	0.6 - VIN	QFN68	8	11	1.85	190			•		•	•	•	•			•	•	•	•	•			•
EN63A0QI	12	2.4 - 6.6	0.6 - VIN	QFN76	10	11	3	227			•		•	•	•	•	•		•		•	•	•			
12V INPUT PRODUCTS																										
EC2630QI	4	8.0 - 13	4.5 - 6.6	QFN36	5.5	5.5	0.9	140			•			•	•	•	•				•	•	•			
EN2340QI	4	4.5 - 14	0.75 - 5.0	QFN68	8	11	3	200			•	•		•	•	•	•					•				
EN2360QI	6	4.5 - 14	0.60 3.3	QFN68	8	11	3	200			•	•		•	•	•	•					•				
EN2390QI	9	4.5 - 14	0.60 3.3	QFN76	10	11	3	235			•	•		•	•	•	•					•				
EN23F0QI	15	4.5 - 14	0.60 3.3	QFN92	13	12	3	325			•	•		•	•	•	•					•				
DDR MEMORY TERMINATION PRODUCTS																										
EV1320QI	3	1 - 1.8	0.5 - 0.9	QFN16	3.3	3.3	0.9	40			•	•				•					•	•		•		
EV1340QI	5	1 - 1.8	0.6 - 1.2	QFN54	5.5	10	3	125	•		•	•				•					•	•		•	•	
EV1380QI	8	1 - 1.8	0.6 - 1.2	QFN	8	11	3	200			•	•				•			•		•	•		•	•	
CURRENT SENSE AND MONITORING PRODUCTS																										
EQC1240QI	NA	2.9 - 14	NA NA	QFN24	4	4	0.75																			

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